St. Petersburg State University

Proceedings of the
4th International Conference

“PROBLEMS OF GEOCOSMOS”

St. Petersburg, Petrodvorets
03–08 June 2002

Editors: V.S. Semenov, A.M. Lyatskaya, M.V. Kubyshkina and H.K. Biernat

Saint-Petersburg

2002
Dr-Current Intensity Variations During Substorm Development

S. A. Zaitseva, T. A. Drobinina, M. I. Pudovkin *

Abstract

According to the concept dominated by the last time, the intensification of the DR-current takes place during the polar substorm development. In the recent papers Iyemori and Rao claim that geomagnetic storms and substorms are independent processes, and SYM-index (essentially the same as Dst-index) tends to decay after the onset of substorms. In this paper we tried to clear up the reason of this contradiction by studying the connection of ring current development with polar substorms basing on the new data: ASY-, SYM-indices describing asymmetric and symmetric parts of DR-current correspondingly and AL-index as a measure of polar disturbances. It is shown that the hourly-mean SYM- and ASY-indices correlate with AL-index ($r = 0.63$ and $0.69$ correspondingly), and the connection between these values becomes worse for strong storms (ASY, SYM more than 100 nT). Besides, at the substorm expansive phase onset, the energy can put mainly to the asymmetric part rather than into symmetric part of DR-current. Empirical $Q$-index based on solar wind parameters describes the energy input into DR-current; $Q$ correlates rather well with SYM, ASY and AL-indices. So, it is possible to say that intensifications of polar disturbances and DR-current take place simultaneously and have the same source.

1 Introduction

Beginning with the 60-th years of the last century there were formed rather distinct ideas on an essential role of the solar wind in the generation and development of both the polar magnetic disturbances and global geomagnetic storms, the main component of which is the magnetospheric ring current (DR-current). In revealed empirical relations which connect values of the AE-index (auroral electrojet) and those of the DR-current with the solar wind parameters, the decisive role is played by the solar wind electric field penetrating into the magnetosphere during disturbances. Investigations of the relationship between the development of polar magnetic disturbances and Dst-variations describing global geomagnetic storms, have shown that the intensification of the DR-current takes place during polar disturbances ([1, 2, 3], and others).

*University of Sankt-Petersburg, Institute of Physics, Petrodvoretz, 198504, Russia, e-mail: zaitseva@geo.phys.spbu.ru
In the recent papers by Iyemori and Rao [4] and Iyemori [5], there is claimed that global geomagnetic storms and substorms are independent phenomena, that is, development of the DR-current is not associated with the substorm appearance; moreover, with the onset of the expansion phase of a substorm, intensity of the DR-current decreases, or its increase becomes slower.

The point of view by Iyemori and Rao was later sustained in some papers [6, 7], and was put in question by Rostoker et al. [8] and McPherron [9].

2 Experimental data

In this paper, an attempt is maid to clear up reasons for so contradictory conclusions on the role of magnetospheric substorms in the DR-current development. For this purpose, the relationship between the development of polar and global magnetic storms is re-examined on the base of new experimental data. In particular, there are used ASY-H and SYM-H indices introduced by Iyemori [10] and characterizing the symmetric and asymmetric parts of the geomagnetic disturbances at low latitudes correspondingly.

![Graph](image)

**Figure 1:** Variations of AU, AL, ASY and SYM-indices during the storm 22.09.1987.

First of all, turn ourselves to Fig. 1 (after [4]) which illustrates variations of various geomagnetic indices during the storm on 22 of September, 1987. As is seen in the Figure, in the accordance with Iyemori, during the period of a rapid increase of the westward auroral electrojet intensity
(17h30m – 18h00m), practically no significant intensification on the SYM-index is observed. At the same time, and seems to be of importance, a rather rapid increase (up to 100 nT) of the asymmetric part of the DR-current takes place.

Figure 2: Dependence of $\text{SYM}_{\text{min}}$ and $\text{ASY}_{\text{max}}$ values on AL-indices taken 1 hrs earlier.

In Fig. 2 there are presented values (hourly-mean values are meant) of SYM-indices at the moments of their minimum and of ASY-indices at the moments of their maximum (ASY-indices are positive by the method of their calculation) in dependence on AL-indices (also hourly-mean values) taken at one hour earlier. The coefficients of correlation between SYM and AL-indices ($r = 0.63$), and ASY and AL ($r = 0.69$) are close to those obtained by Iyemori [5] for Dst and AL-indices, though $r$ (ASY, AL) is a little bit higher than $r$ (SYM, AL). And this is not surprising if we take into account for example Fig. 1 in which one can see, as was said above, an obvious re-distribution of the energy incoming into the DR-current from the symmetric part of the latter to the asymmetric one.

In one of our previous papers, there was obtained an empirical function $Q$ which describes the rate of the energy input into the DR-current in dependence on the solar wind parameters [11]:

$$Q (\text{nT/s}) = -3.5 + 4.3v(0.5\sigma - B_z) \cdot 10^{-3},$$

where $v$ is the solar wind velocity measured in km/sec, $B_z$ is the $z$-component of the IMF (in nT), $\sigma$ is the IMF variability (also in nT).

Let us see now in what way this function $Q$ is connected with the AL-index characterizing the intensification of the westward electrojet. In Fig. 3, values of $Q$ calculated for every hour of 3 storms (07.02.1967; 27.02.1968; and 16.03.1974) are shown in dependence on AL-indices at the same hours; correlation coefficient equals $r = 0.74$. This result may be explained if one supposes that the energy enters both the DR-current and the polar ionosphere simultaneously.

In Fig. 4, a sample of Dst-variations (observed and calculated according to the model [11]) for storms on 07–10.02.1967 is presented. In the same figure, one can see also values of the solar wind dynamic pressure $P_d$, IMF $B_z$, the rate of the energy input into the DR-current $Q$, AL-indices. In this Figure mentioned above a rather good connection between the $Q$-function and AL-index is clearly seen. Relatively close coincidence of $\text{Dst}_\text{exp}$ and $\text{Dst}_\text{calc}$ (which takes place not only for this storms, but also for 20 other geomagnetic storms, that is for about 1200 hours
Figure 3: AL-indices in dependence on the Q-function describing the energy input into the DR-current.

[12]) is explained not only by properly chosen function Q, but also by the taking into account variations of the DCF-field and characteristic time of the DR-current decay.

3 Conclusions

The data presented above permit us to state that the conclusion of Iyemori on the independent development of global magnetic storms and substorms should be re-examined very thoroughly. According to our study, the energy fluxes to the DR-current and to polar disturbances take place simultaneously and have the same source: solar wind. It has to be noted that initially the energy may enter the asymmetric part of the DR-current (see Fig. 1). It is difficult to say now what part of this energy and in what time will be added to the symmetric part. Besides, without taking into account the DCF-field variations, all the estimations will not be totally correct, especially at the onset of the substorm when DCF-field may be relatively large.

Acknowledgement. The SYM and ASY-indices were provided by T. Iyemori via the WDC-C2. We would like to acknowledge the support of the work by the “Leading Science School Programme”, grant RFBR No 00-15-98555.
Figure 4: Variations of observed and calculated Dst-values, solar wind dynamic pressure $P_d$, $B_z$ IMF, function $Q$ and AL-index for the storm 07–10.02.1967.

References


